4th JASTIP Symposium, July 3, 2017

Bioenergy for Mitigation of Global Warming

Atsushi Tsutsumi

SATREPS, JST

Collaborative Research Center for Energy Engineering
Institute of Industrial Science
The University of Tokyo, Tokyo, Japan

Bioenergy for Mitigation of Global Warming

Contents

About SATREPS

- ☐ Environment and Energy
- ☐ Bioresource Utilization
- ☐ Disaster Prevention and Mitigation
- ☐ Infectious Diseases Control

Global issues need international collaboration.

“Strengthening S&T cooperation with developing countries for resolving the global issues”

Aims of SATREPS

1. Enhancing Cooperation in Science & Technology

   ～Building win-win relationships between Japan and developing countries～

2. New Technology, New Knowledge, Innovations

   ～ Addressing global issues and advancing science ～

3. Capacity Development

   ～ Boosting self-reliant R&D capacity and sustainable research systems, training human resources and coordinating networking between researchers ～

Practical Utilization/Implementation

of research outcomes

～Expecting outcomes to make a real contribution to society ～

Science & Technology × Official Development Assistance（ODA）

Science and Technology

•S&T Competitive Fund, Promoting STI

×

International Cooperation

•ODA, Official Development Assistance

Meeting Global Needs

•Resolving global issues and contributing to the science and technology community

×

Meeting Local Needs

•Capacity development to address issues emerging as local needs in developing countries

Japan's Capabilities

•World-leading technology, proven research capacity

•Soft power

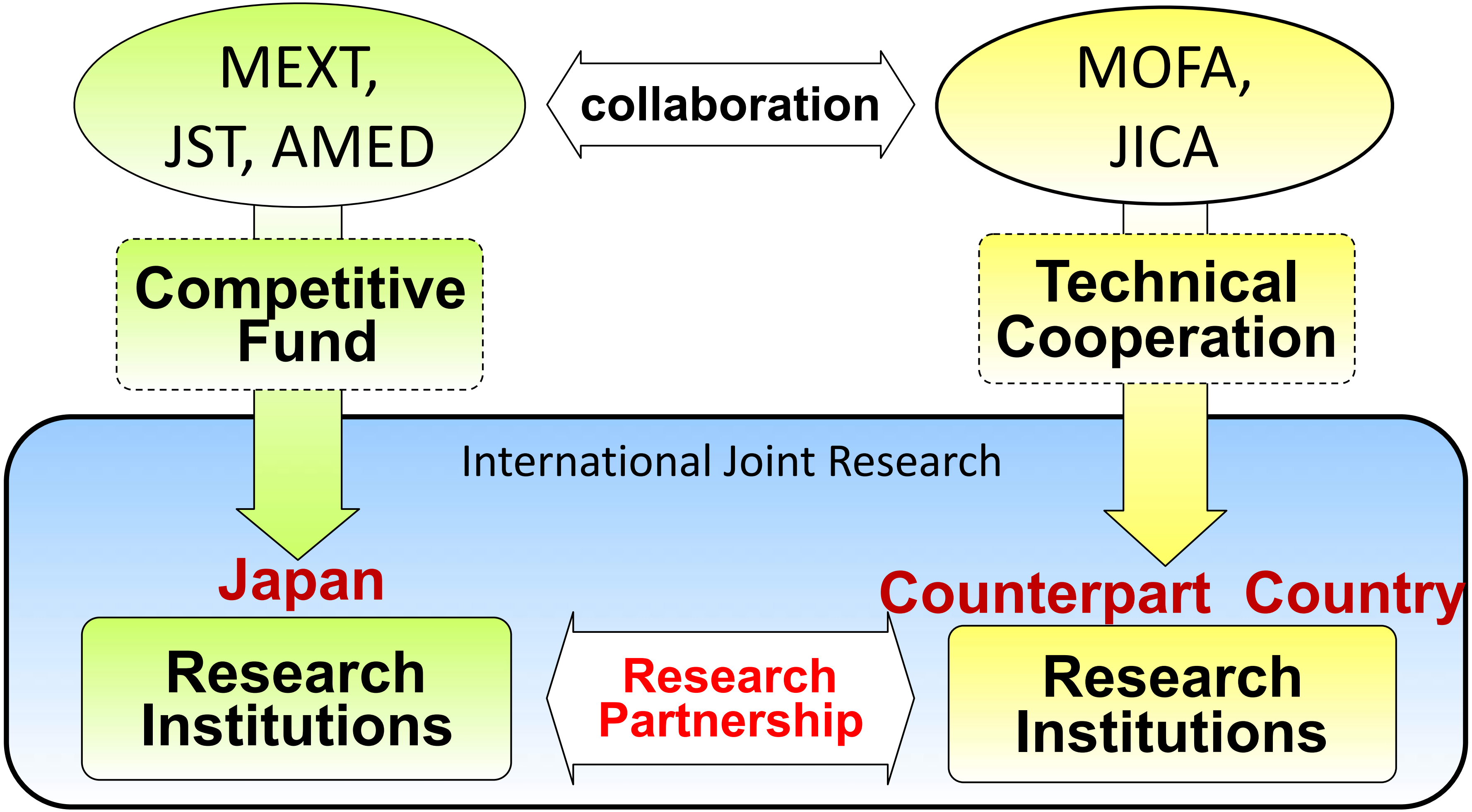
×

Developing Countries' Capabilities

•Direct experience, knowledge, and data needed for research on global issues

•Potential to contribute to the global economy through new markets and industries

SATREPS program structure



MEXT: Ministry of Education, Culture, Sports, S&T
JST: Japan Science and Technology Agency
AMED: Japan Agency for Medical research and Development
MOFA: Ministry of Foreign Affairs
JICA: Japan International Cooperation Agency

Research Period : 3-5 years
Research Funding
Approx. JPY96 million / project / year (USD* 872,000)
Funding split: JST: Approx. JPY36 million (USD* 327,000)
JICA: Max. JPY60 million (USD* 545,000)

Research Areas

4 fields 5 areas


□Environment and Energy

・Global-scale Environmental Issues

Climate change mitigation & adaptation, Safe water supply, Biodiversity conservation..

・Low-carbon Society/energy

Biomass energy, Energy efficiency, Renewable energy..


□Bioresource Utilization

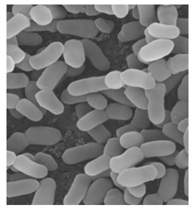
Breeding and cultivation technology, Bioresource management..

□Disaster Prevention and Mitigation

Natural disaster mechanisms (Earthquakes, Volcanic..), Disaster mitigation..

□Infectious Diseases Control

Diagnostic tool, Vaccines, Therapeutic products development
(Avian influenza, HIV/AIDS, Dengue fever..)

FY2015～ JST → AMED

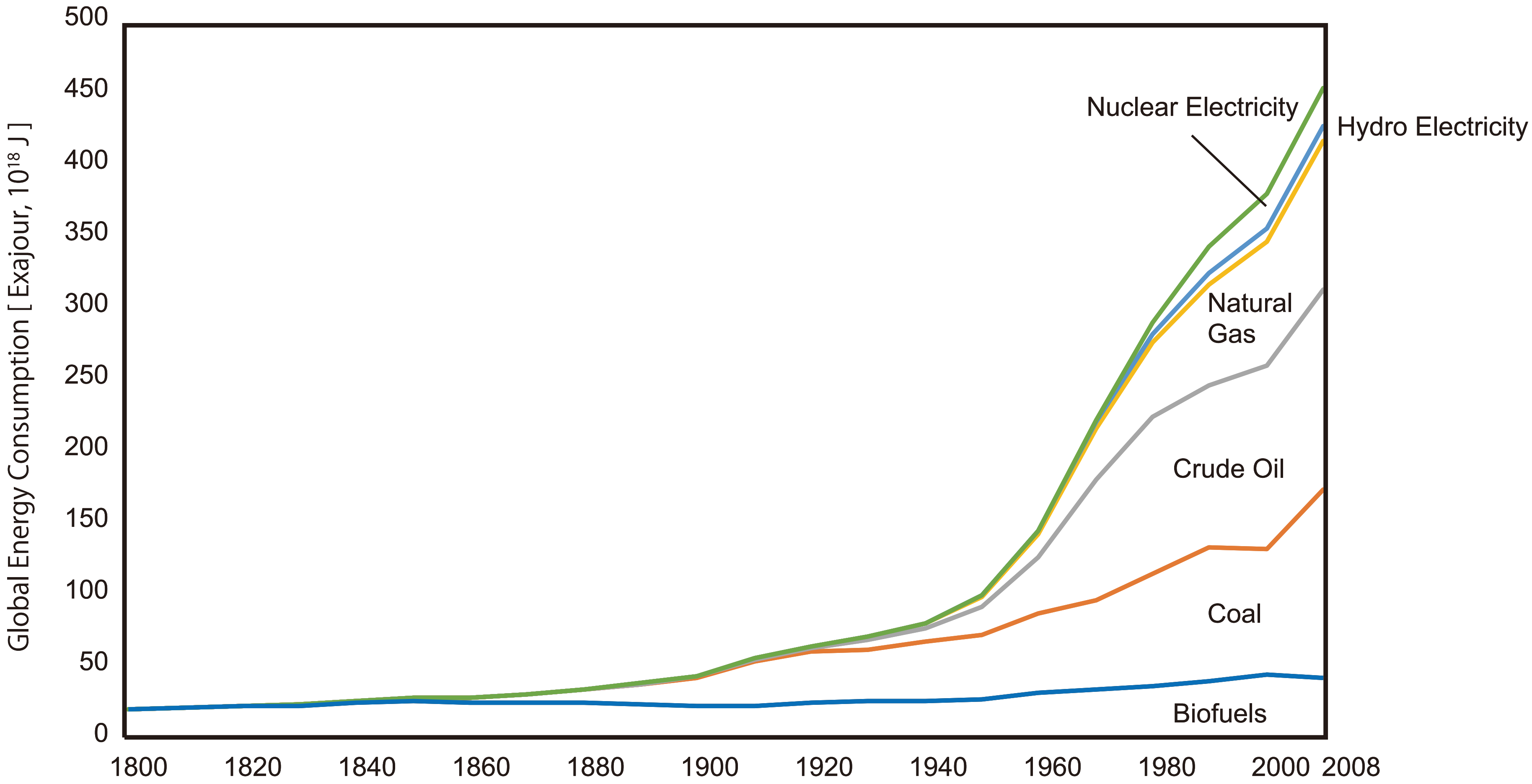
※AMED：Japan Agency for Medical research and Development

SATREPS's contribution for SDGs

Bioenergy for Mitigation of Global Warming

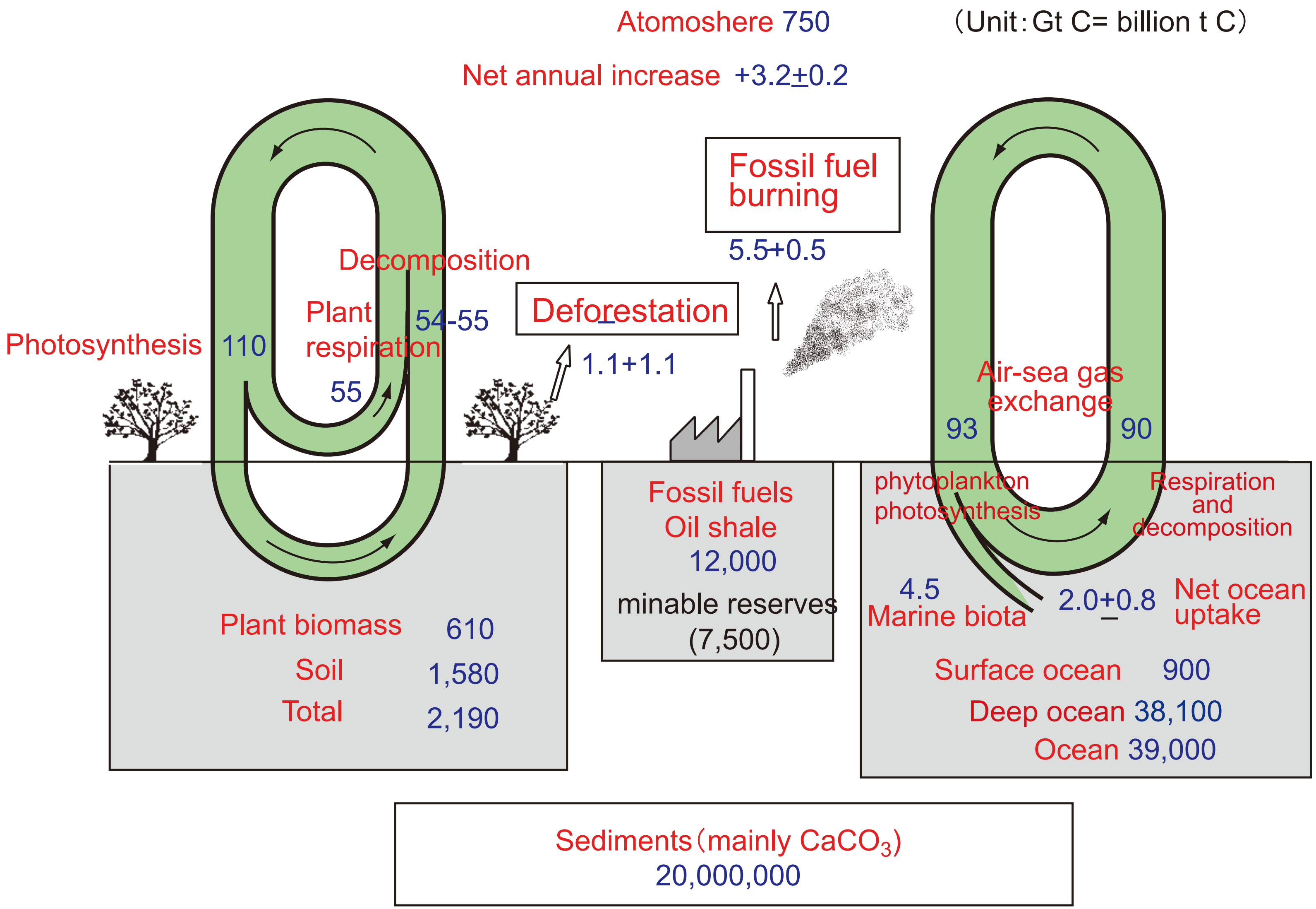
Contents

Global Energy Consumption



- We are consuming a huge amount of energy.
- The CO_2 emission due to the combustion of fossil fuels causes the global warming.

Carbon Cycle



missing sink (1.1+5.5)-(3.2+2.0)=1.4

Fossil fuel burning → Renewable energy

Deforestation → Forest conservation

Mitigation of Global Warming for Sustainable Society

Renewable Energy

- shift to low-carbon fuel
- renewable energy such as solar, wind, biomass

Energy Saving

- heat recovery and heat cascading
- high-efficient equipment
- energy efficient utilization

Carbon Capture and Storage (CCS)

- capturing waste CO_2 from power plants, transporting it to a storage site, and geological sequestration.

Carbon Capture Storage (CCS)

- CCS process consists of CO_2 recovery section and storage section.
- In the CCS process, large amount energy consumes in CO_2 capture section in which consume 4.1 GJ/t-CO_2 using a chemical absorption process (ex. Monoethanol amine, MEA)
- As a result of increasing the energy consumption, the power generation efficiency is decrease by 8-10 point.

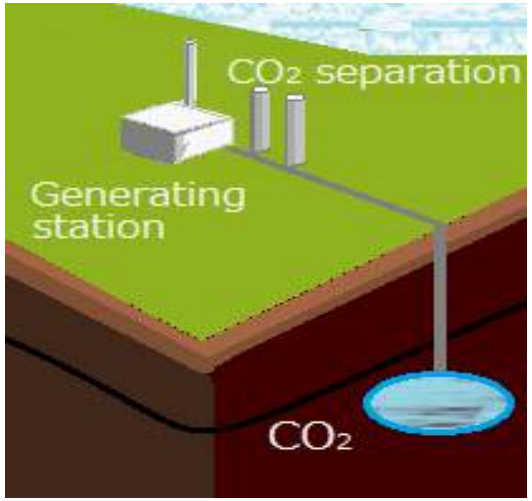


Figure. CCS process

Table. Carbon footprint in power generation section [Gt-C/year]

※In the parentheses, these value indicate the percentage for coal emission.

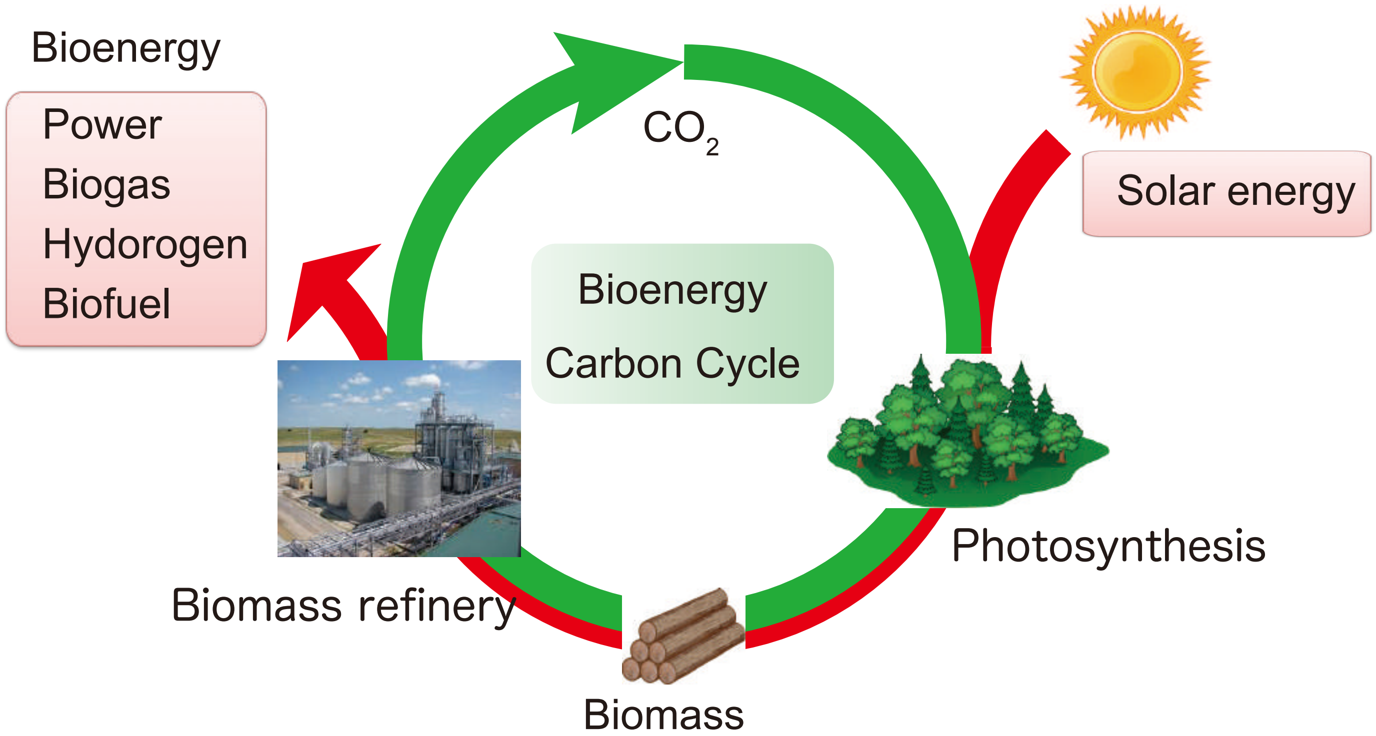
CCS contributes one-sixth of total CO2 emission reductions required in 2050.

14% of the cumulative emissions reductions through 2050 against a business-as-usual scenario (6DS)

Renewable energy

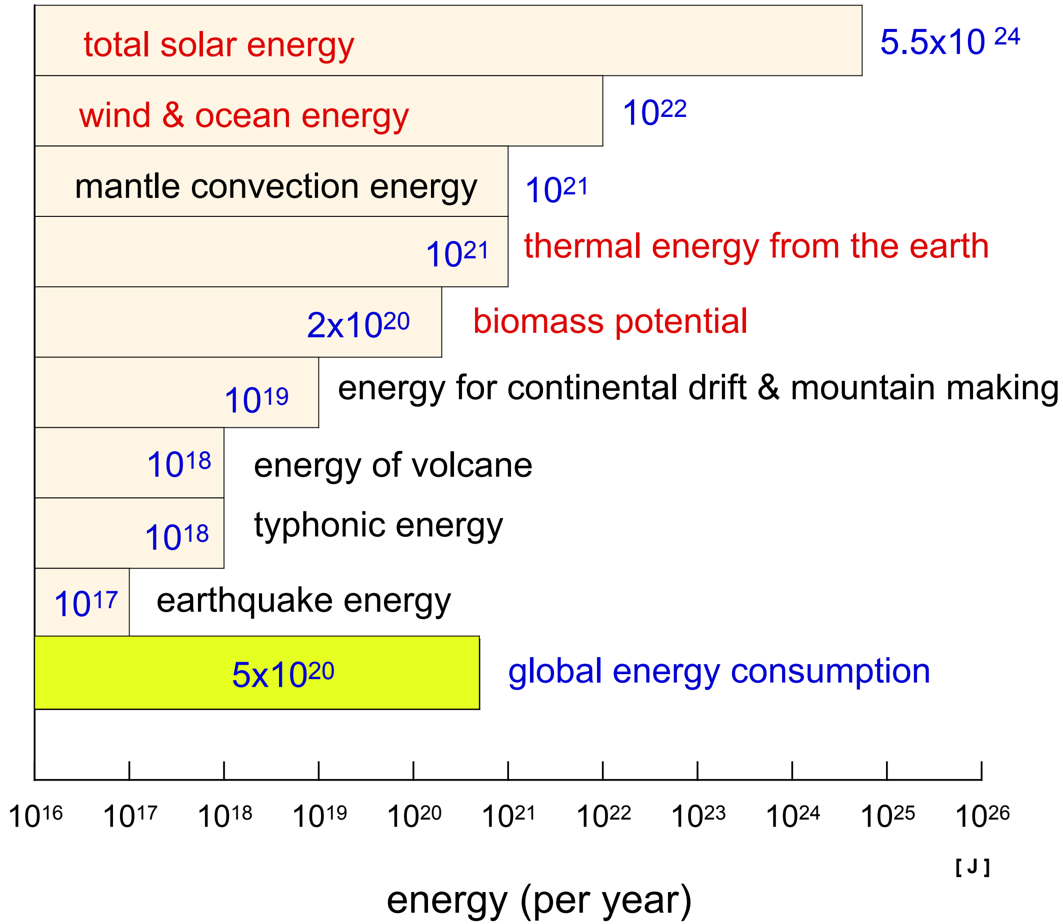
Wind power

Solar photovoltaics



Bioenergy

Terrestrial Energy Potential



A large amount of solar and wind energy use might cause the climate change.

↓

More efficient use of bioenergy is essential.

Energy saving technology

Bioenergy for Mitigation of Global Warming

Contents

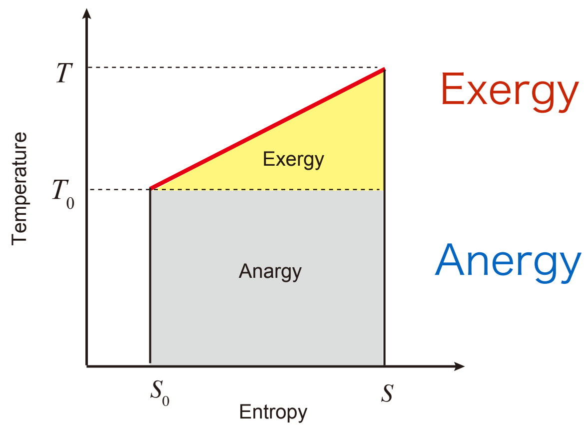
Exergy, Exergy Rate

$$\Delta H = H - H_0 = Ex + T_0 \left(S - S_0 \right)$$

Energy　Exergy　Anergy

Exergy *Ex*

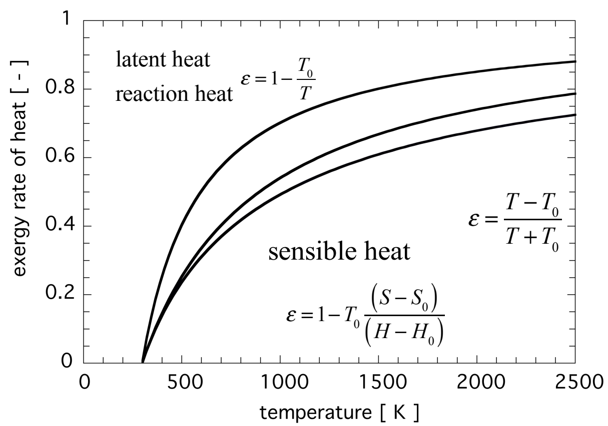
- the maximum useful work obtainable as a system comes into equilibrium with environment



Exergy rate ε

- rate of energy to energy(enthalpy)
- a measure of energy quality

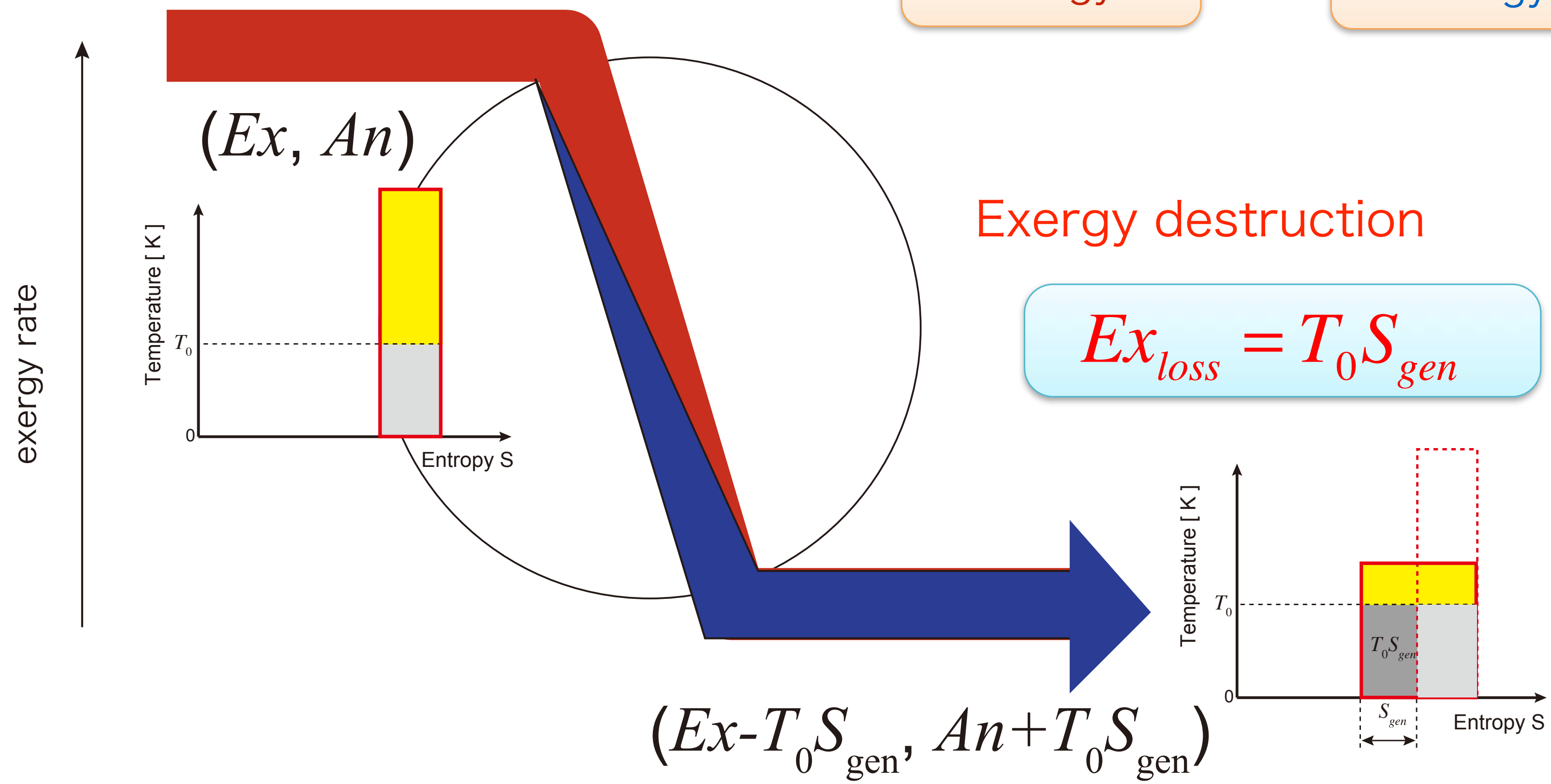
$$\varepsilon = \frac{\text{exergy}}{\text{enthalpy}}$$



Exergy Destruction in Energy Conversion Process

$$-\Delta H = Ex + An = \left(Ex - T_0 S_{gen}\right) + \left(An + T_0 S_{gen}\right)$$

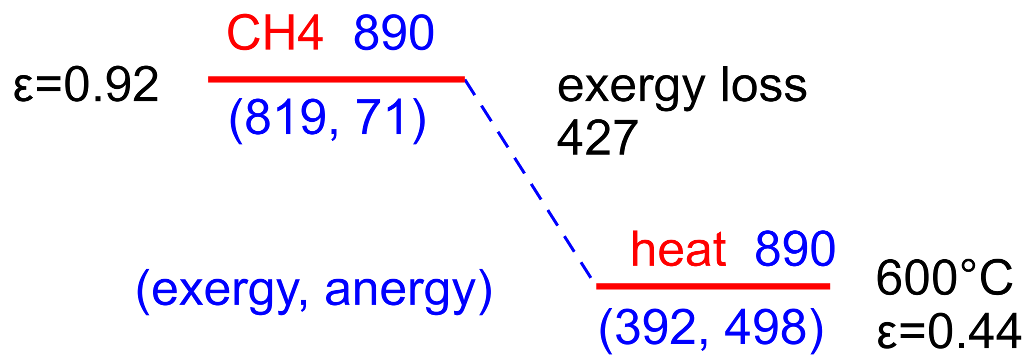
Exergy　　Anergy



- Energy is conserved. (-ΔH=const.)
- Exergy destruction takes place due to the irreversibility
- Exergy is transformed into anergy

Exergy Destruction in Combustion Process

Combustion is an energy conversion process from chemical energy with higher exergy rate to thermal energy with lower exergy rate

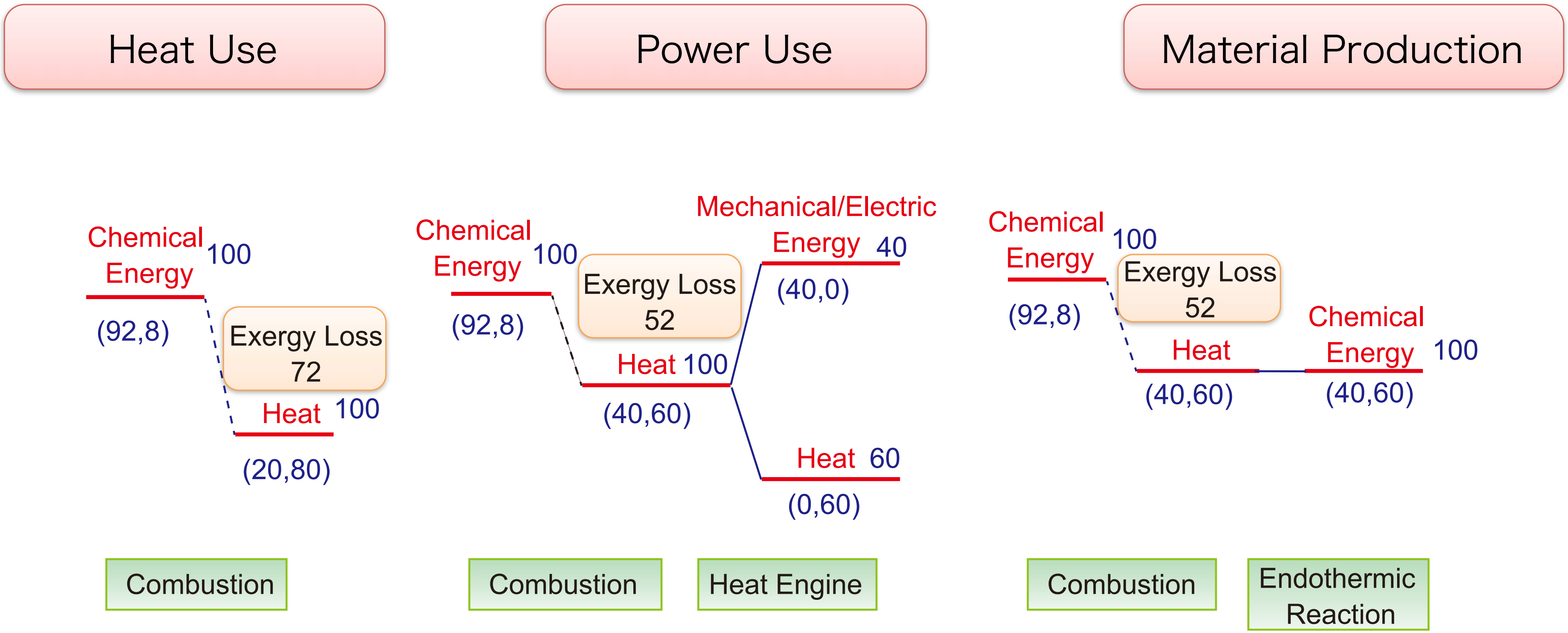


Exergy destruction occurs in the combustion process because exergy rate of heat is lower than that of fuel

It is most essential for the energy saving and efficient utilization to reduce the exegy loss in combustion processes

- **heat generation without fuel consumption**
- **reduction of exergy loss in fuel consumption**

Energy Production and Utilization



In the initial stage of energy production, chemical energy is converted to heat through combustion, in which a large exergy destruction takes place.

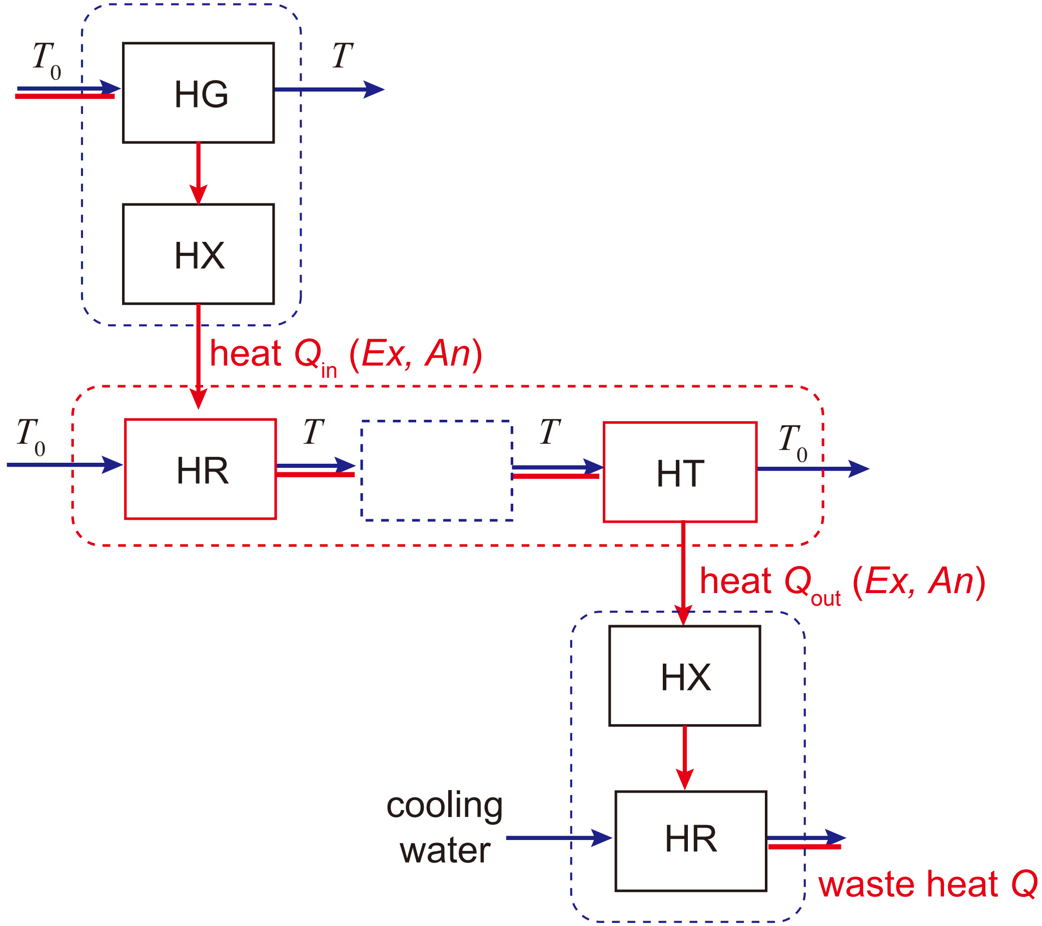
Heat Recycling for Heating and Cooling System

Heat Generation Module

Combustion Heating
Heat pump

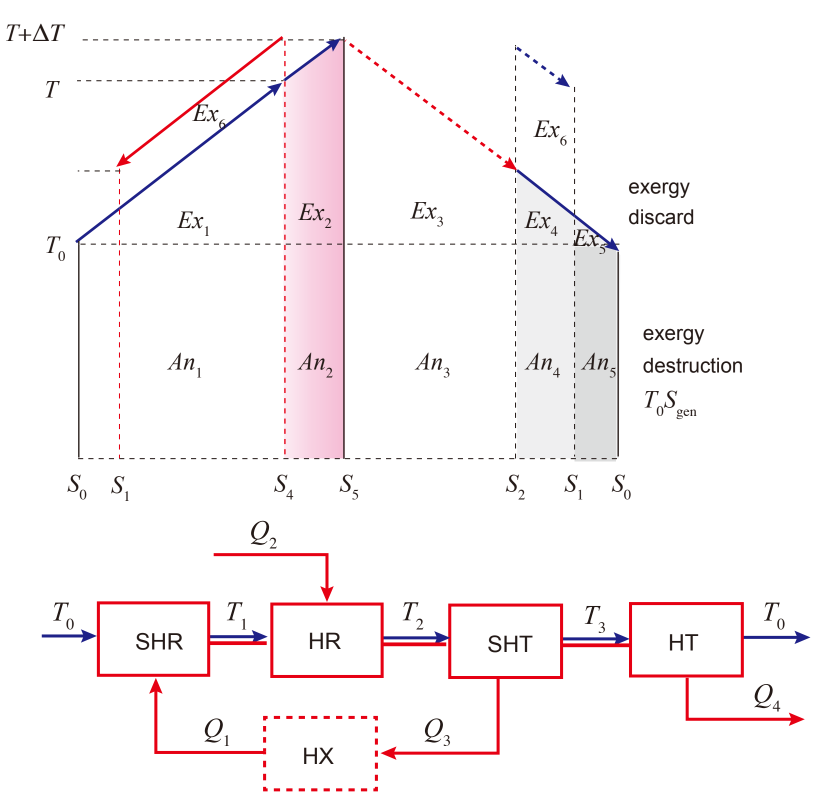
Heating and Cooling Cycle Process Module

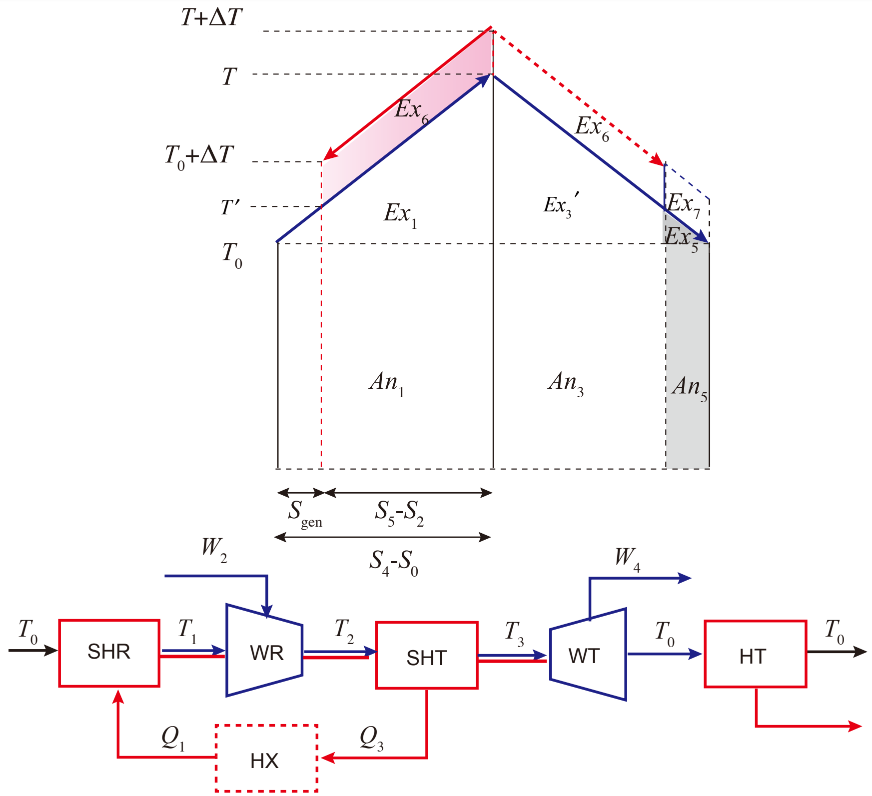
Heat Removal Module



- Heat input is equal to heat output.
- No exergy destruction takes place in the heating and cooling cycle process.
- Exergy destruction takes place only in the heat generation and heat removal modules.

Self-heat Recovery vs Self-heat Recuperation





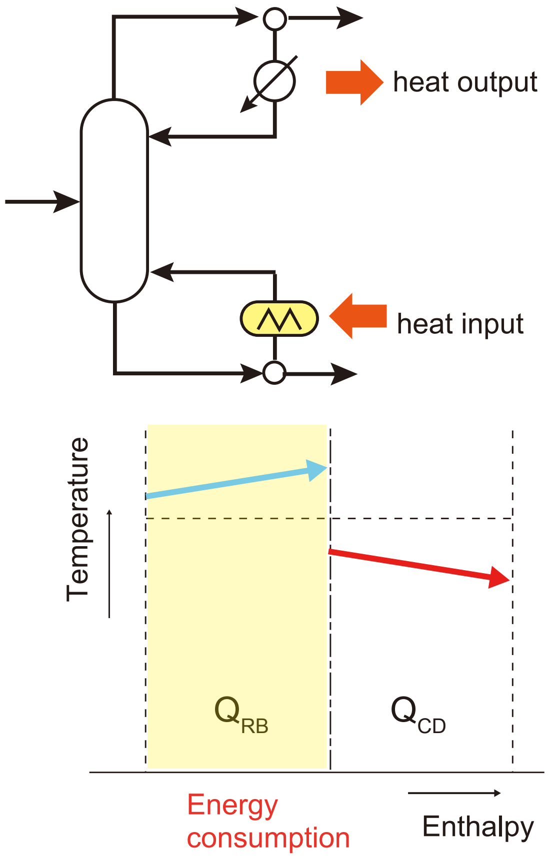
Combustion heating	Self-heat Recovery	Self-heat Recuperation
Q	$\frac{\Delta T}{T-T_0}Q$	$\frac{2\Delta T}{T+T_0}\left(1-\frac{\Delta T}{T-T_0}\right)Q$
heat	heat	work
100	9.8	2.3

Innovative energy saving

Application of Self-heat Recuperation Technology to Distillation

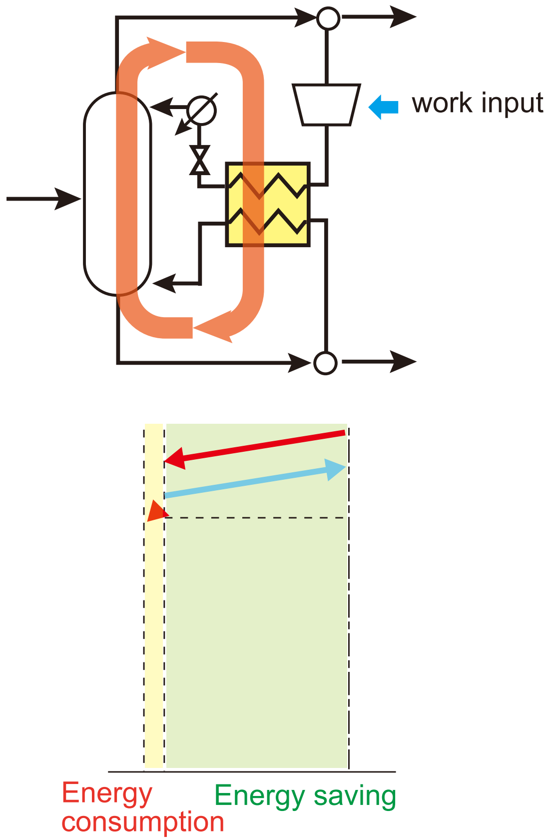
About 40% of energy consumption in petrochemical industry is due to the distillation

Conventional distillation



Heat supplied to reboiler is wasted in the condenser

Self-heat recuperative distillation



Self-heat is recycled by adding work
No adding heat

Energy consumption is reduced to 15% (85% saving)

Kansha, Yasuki, Naoki Tsuru, Chihiro Fushimi and Atsushi Tsutsumi, Integrated Process Module for Distillation Processes Based on Self-Heat Recuperation Technology, *J. Chem. Eng. Jpn*, **43**(6), 502-507, (2010)

Pilot Plant of Self-Heat Recuperative Bioethanol Distillation System

Feed rate: 400 kg/h
Feed: 10wt% ethanol
Distillate: 90wt% ethanol

	Steam Utility	Power (compressor)	%
Heat Recovery	4.6 MJ/L-EtOH	—	100
SHR (Simulation)	—	0.77 MJ/L-EtOH	17 (50)
SHR (Pilot plant)	—	0.65 MJ/L-EtOH	14 (43)

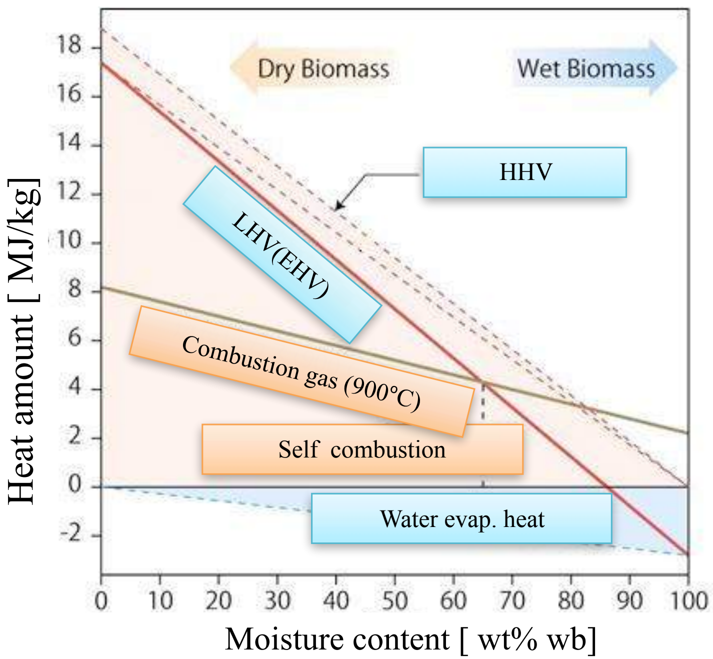
- () is calculated by Steam Utility = Power ×3
- Compression efficiency was estimated to 50% in simulation, but it was 58% in Pilot plant.

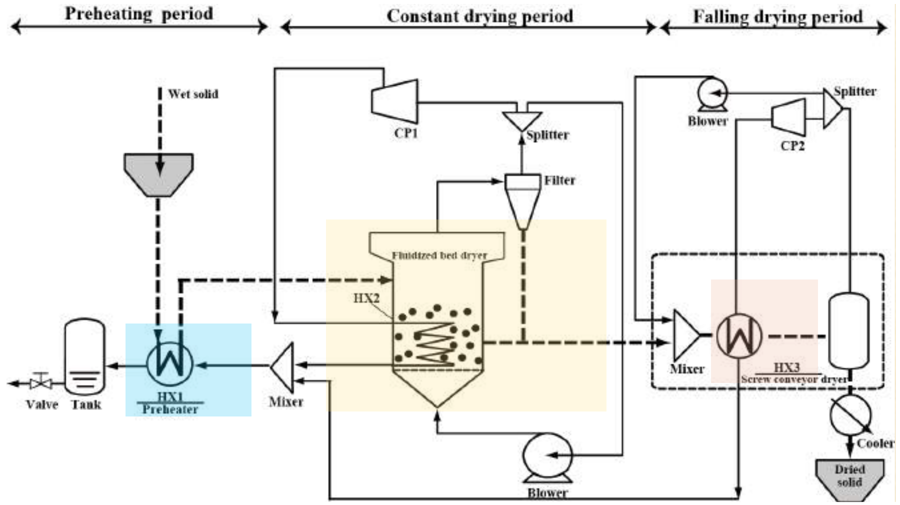
Nippon Steel Sumikin Engineering, Kitakyushu Environmental Technology Center

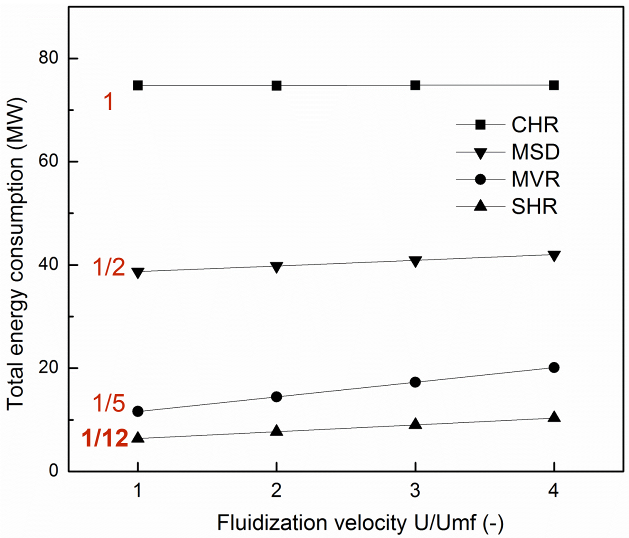
The energy required for distillation is reduced to about 14% of the conventional counter parts (86% energy saving)

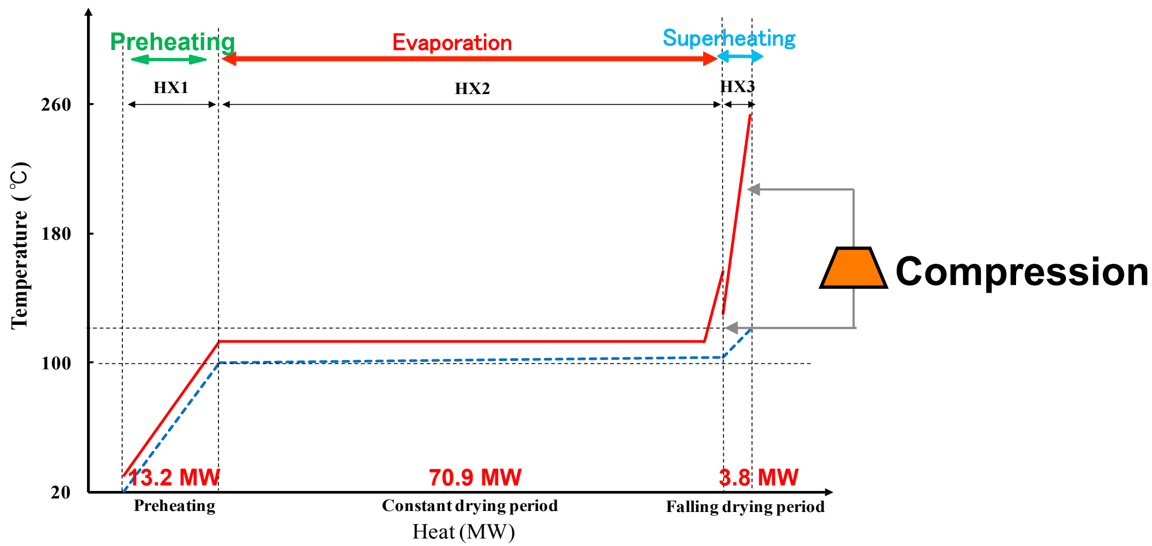
Self-Heat Recuperative Biomass Drying

High energy demand for drying because of large latent heat of water evaporation









Energy consumption can be reduced to 1/12

Self-heat recuperation is adaptable for various unit operation

•Distillation	86% energy saving （reduced to 14%)
•Desulfurization Process	75% energy saving （reduced to 25%)
•Cryogenic Air Separation	40% energy saving
•Thermal Desalination	78% energy saving
•CO2 Chemical Absorption	68% energy saving
•Drying Process	86～92% energy saving
•Methanol Synthesis	85% energy saving
•BDF production	80% energy saving
•PSA (pressure swing absorption)	70% energy saving

Green Innovation: Paradigm Shift in the Heat Utilization

Energy Cascading	→	Exergy Recuperation
Combustion Heating		Heat Circulation by Self-heat Recuperation

- Heat is generated by the combustion of fuels, leading to a large exergy destruction.
- Heat is recovered and reused at lower temperature. But, heat addition is required.
- Large energy consumption

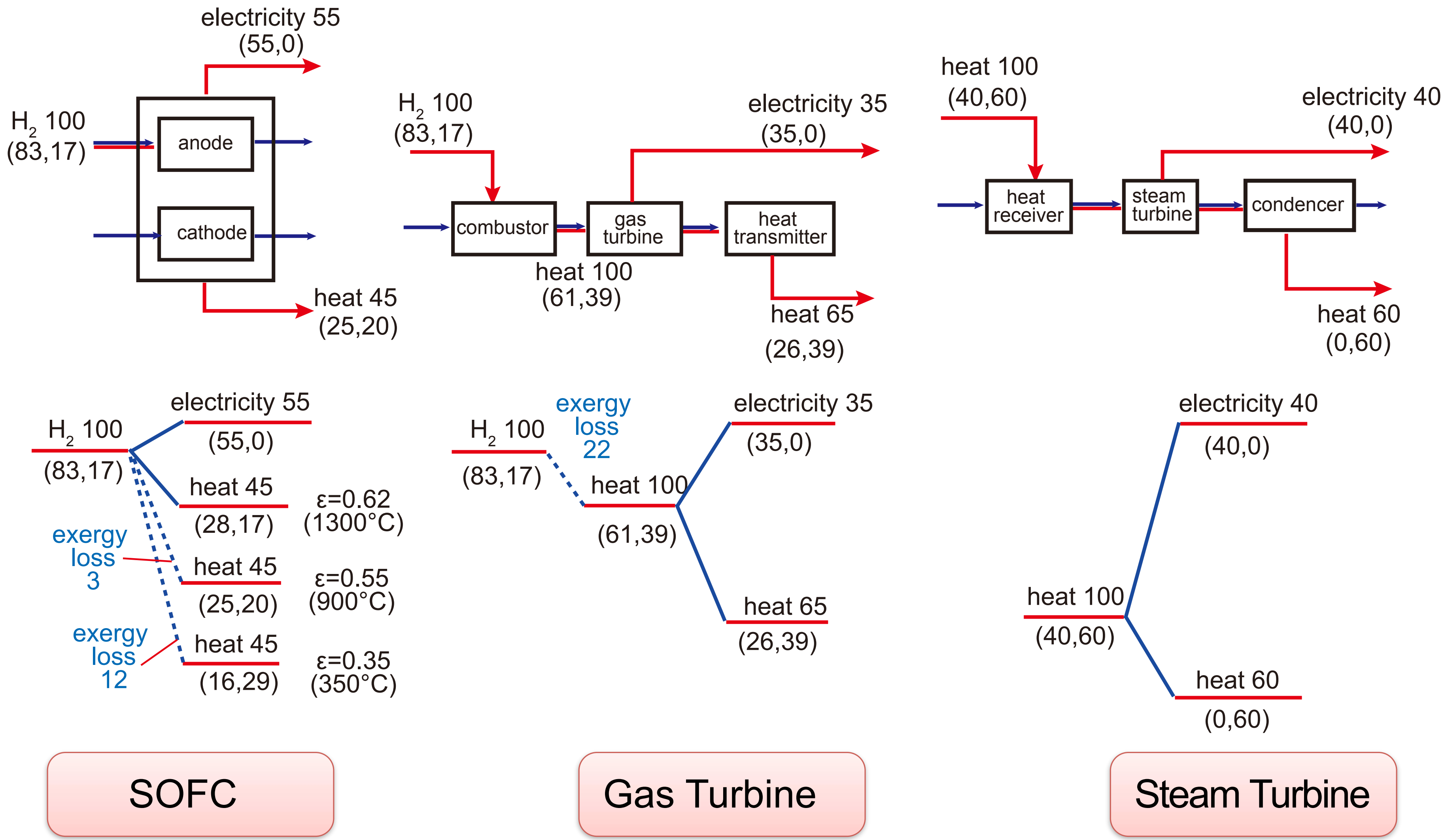
- No more combustion!
- Heat can be recuperated by adiabatic compression and be recycled with no addition of heat.
- Exergy loss is minimized to the minimum work for heat circulation

Self-heat recuperation applicable to all thermal processes

Energy consumption can be reduced to 1/5～1/25 (1/2～1/10)

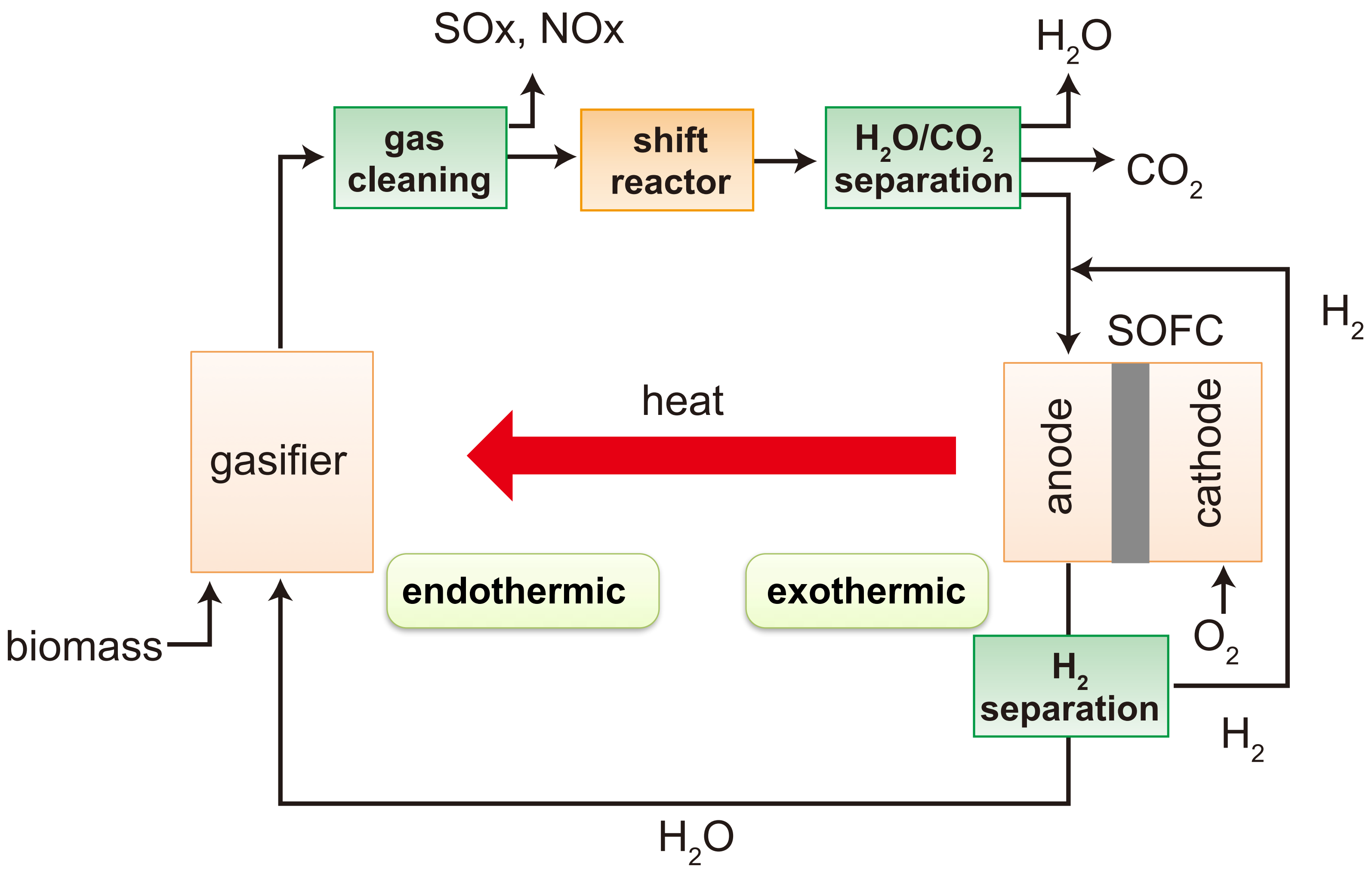
No combustion leads to zero emission of CO_2

SOFC, Gas Turbine, Steam Turbine



- In gas turbine and steam turbine power generation the exergy destruction takes place mainly during combustion.
- The exergy loss of SOFC is very small (3%) because of no combustion.
- The effective utilization of waste heat from SOFC is essential.

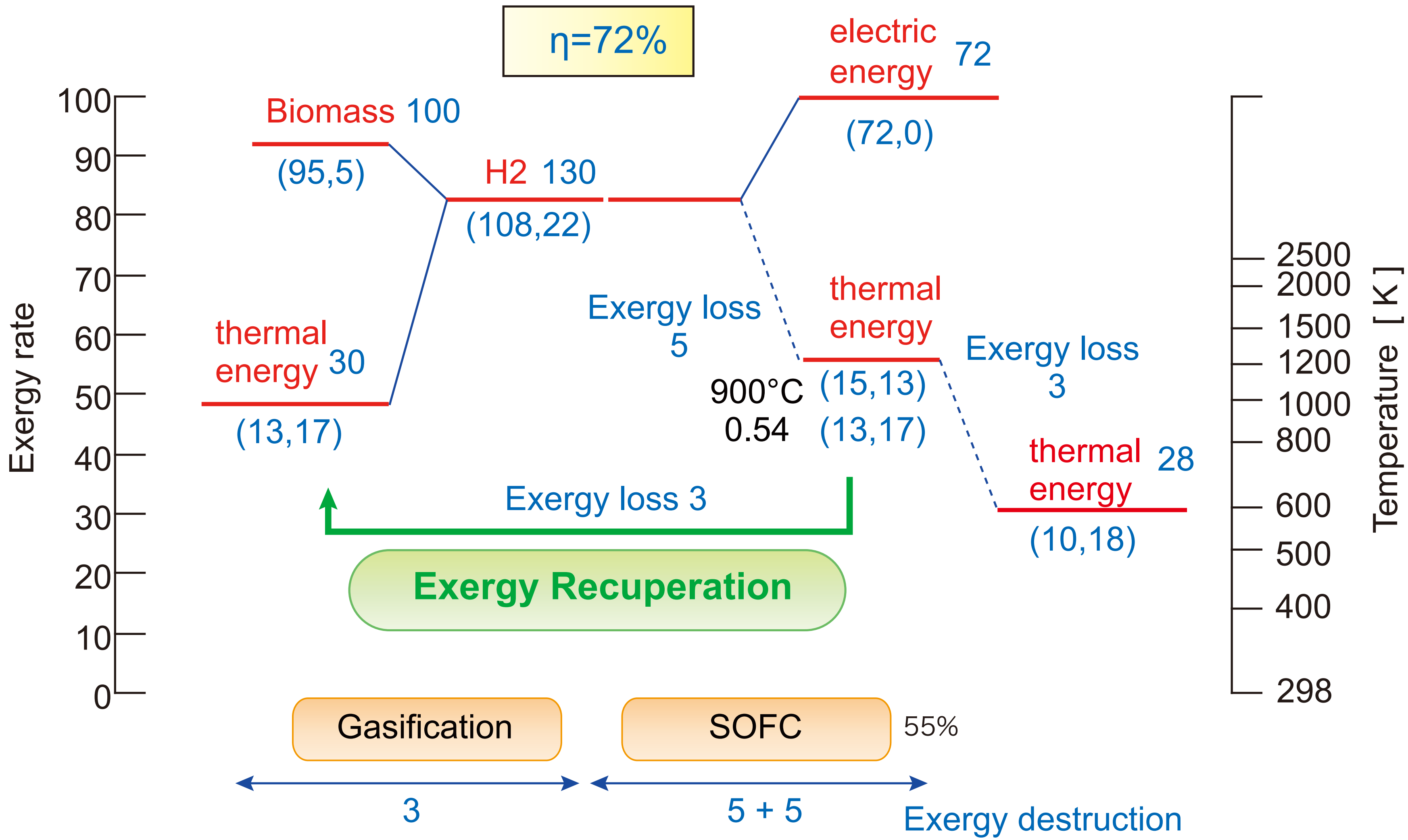
Exergy Recuperative Gasification Integrated with SOFC



- Stable SOFC performance (no carbon deposition issues)
- No air cooling of SOFC – only pure O_2 is fed to cathode
- Gas turbine can be eliminated

A. Tsutsumi, *Chem. Eng.*, **75** (2011) 578-581 (in Japanese)

Integrated Exergy Recuperative Biomass Gasification SOFC System



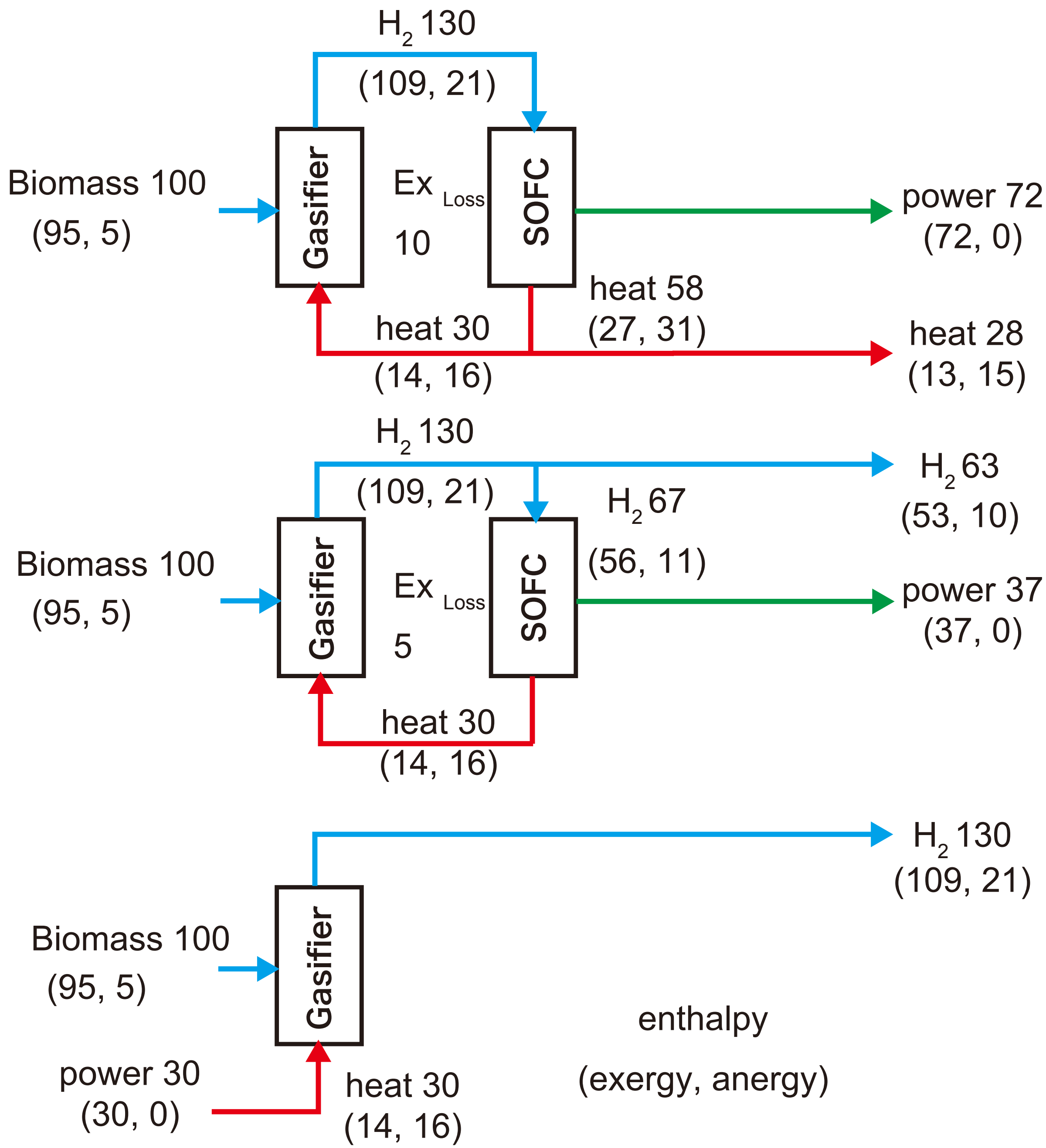
- In the gasification process waste heat from SOFC is recuperated to produce hydrogen (130%) because of endothermic biomass gasification, resulting in high power generation efficiency (72%).
- Gas and steam turbines can be eliminated from power generation system.

Super Integrated Biomass Gasification-SOFC

Power and Heat Cogeneration

Power and Hydrogen Coproduction

Power to Biomass Hydrogen



Green Innovation: Paradigm Shift in the Power Generation

Heat Engine → **Fuel Cell**

Heat Generation by Combustion

- Heat for heat engine is generated by the combustion of fuels, leading to a large exergy destruction.
- There is a limit to the power generation efficiency.

Exergy Recuperative Hydrogen Production

- No more combustion!
- Waste heat of fuel cell can be recuperated to use for the endothermic reaction (hydrogen production).
- High power generation efficiency over Carnot efficiency is expected.

There is no limit of Carnot efficiency

High power generation efficiency is expected (60-80%)

GHG can be reduced

Green Innovation: Paradigm Shift in Energy Science and Technology

the energy-throwaway society

- A huge amount of fossil energy is converted to thermal energy through combustion.
- In the combustion process a considerable exergy destruction takes place, in which the exergy is transformed to anergy.
- Although energy is conserved, all of energy is thrown away.

To reduce the energy consumption the technological innovation for energy utilization is essential.

- Self-heat Recuperation Technology
- Highly Efficient Power Generation
- Material and Energy Coproduction

sustainable society

low-carbon society

- No more combustion
- Energy can be recycled by the exergy recuperation to minimize exergy loss, leading to the drastic reduction of energy consumption

The End